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Abstract

CONTROL, STABILITY & PROTECTION OF A GAS-COOLED, GRAPHITE-MODERATED REACTOR

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The paper is limited to control, flux stability, and protection against reactivity faults in large CO_2-cooled, graphite-moderated reactors of the type now in operation or under construction in Great Britain. The steady state design limitations are stated, derived from limits set by fault criteria in relation to fuel element properties. The difficulties of correctly flattening the radial flux shape of such a reactor are discussed, with examples.

The assumptions made in deriving the necessary control rod investment to shut down a reactor under all conditions of temperature and irradiation are examined and it is shown that, for maximum economy in investment, the control rod pattern must be carefully chosen. The effect of locally removing control rods from a fully shut-down reactor is illustrated.

Reactor flux stability is examined, both in the radial/azimuthal and axial directions, and it is concluded that some form of control is necessary to prevent the former, but not the latter, possible instabilities. The use of lightly absorbing control rods for this purpose is described, using a typical large reactor as an example. Although such rods have been provided against instabilities, it has been found convenient to incorporate them into an overall reactor control scheme. Faults in the control system of these rods can, however, lead to locally high temperatures, and a full and detailed examination is made of this type of fault condition within the reactor.

The problems associated with reactor start-up are discussed and the development of multi-group bulk control rod lifts is traced starting from the

single group lift as used at Calder Hall. It is shown that axial flux distortion is thereby reduced, but that, unless the control rod pattern is carefully chosen, radial/azimuthal flux distortions can give local high temperatures in the fuel elements. Symmetry of core layout is emphasised as a design concept.

Bulk reactivity faults, caused by all rods moving simultaneously, are shown to be very severe, although their severity depends upon the relative disposition of the groups of rods when the reactor passes through criticality; the necessity to provide interlocks to high safety standards to prevent the occurrence of such faults is demonstrated. It is shown, nevertheless, that fast start-ups can be achieved on this type of reactor provided certain basic design requirements can be economically met.

Part-load operation of a reactor is discussed, and methods of overriding the xenon poison following a load reduction are described.

The recognition of the existence of many of the problems discussed, has been due to the development of improved methods of calculation using large digit and analogue computing machines. Using the former, a method of calculation is described which enables reactor transient conditions in 3 dimensions to be examined, and another one-dimensional method for transient calculations is also presented; these have been used in producing the curves shown in this Paper.